International Journal of Agricultural
Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 7, Issue 4, Aug 2017, 505-510

PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR) FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

As Green revolution' seems to have started slowing down and in some cases crop yields have either remained stagnant or declined, besides causing other environmental health problems. For facilitating nutrient uptake and improving soil organic matter status, Plant Growth Promoting Rhizobacteria (PGPR) technology is widely recognized, offering the use of soil microorganisms in practicing sustainable and climate resilient agriculture, eliminating the use of chemical fertilizers and pesticides. PGPR is also proved to promote the activities of bioremediation and biodegradation of hazardous substances present in soil, air or water. It promotes plant growth and development by using their own metabolism through a variety of direct or indirect mechanism such as biological nitrogen fixation, increasing the availability of nutrients in rhizosphere, enhancing the absorption of iron through siderophore production and production of phytohormones. It also used as bio control agents (bio pesticides) providing resistance against plant pathogens by synthesising a variety of antibiotic and antifungal compounds. Thus, PGPRs can have wide applications in the restoration of waste lands and agricultural lands and can be named as sustainability indicator in terms of agriculture and environment as they are used as bio fertilizers, bio control agents and soil fertility improvers promoting agriculture in eco-friendly manner.

KEYWORDS: PGPR, Sustainability Indicator, Bio Fertilizers & Bio Control Agents

Received: Jun 28, 2017; **Accepted:** Jul 20, 2017; **Published:** Jun 29, 2017; **Paper Id.:** IJASRAUG201765

Original Article

INTRODUCTION

Currently, Green revolution' seems to have started slowing down and in some cases crop yields have either remained stagnant or declined, besides causing other environmental health problems. Imbalanced nutrient management and decreased soil organic matter are the main indicators of yield decline. Besides this, climate change also affects the soil microbial biodiversity, physico-chemical properties and nutrient availability of soil. Thus, there is need to develop sustainable, climate resilient and adaptive agricultural practices. Agricultural sustainability is the foremost important part of the sustainable development as it is one of the major sources of negative environmental consequences. Soil microbes are known to play essential role in environmental and agricultural sustainability from the time of their discovery. Soil microbes which are found associated with plants have the capability to be utilised as bio fertilizers to overcome the problems related to soil salinity, fertility, degradation, habitat loss and lowering environmental stress (Glick, 2010). The PGPR technology is one such approach of late 1980s in fields of biotechnology offering the use of soil microorganisms in practicing sustainable and climate resilient agriculture, eliminating the use of chemical fertilizers and pesticides. Rhizospheric microorganisms promoting plant growth promotion activity were classified as Plant Growth Promoting Rhizobacteria(PGPR). PGPR is basically root colonizing bacteria that have multifunctional role as it exert

beneficial effects on plant growth and development and soil health. Besides that, PGPR is also proved to promote the activities of bioremediation and biodegradation of hazardous substances present in soil, air or water (such as heavy metals, organic pollutants, etc).

TYPES OF PGPR

Plant Growth Promoting Rhizobacteria are the soil microbes found in the atmosphere around the plant's root known as rhizosphere. There are basically two groups of Rhizobacteria; endophytic (symbiotic) and ectophytic (non-symbiotic) or rhizospheric. Rhizobacteria such as *Bacillus, Pseudomonas, Serratia, Burkholderia, Arthrobacter, Micrococcus, Agrobacterium, Flavobacterium, Azospirillum,Azotobacter, Rhizobium, Bradyrhizobium, Mesorhizobium, Allorhizobium, Azorhizobium* and *Frankia* can be utilised as PGPR *Rhizobacteria* (Table 1).

Table 1: Applications of PGPRS in Various Plant Species in Combating Different Environmental Problems

S. No.	Plants	Types of PGPR	Effects	References
1.	*Prosopis juliflora* *Lolium multiflorum*	*Bacillus, Staphylococcus, Aerococcus*	Improved efficiency of phytoremediation of Chromium, Copper, Lead and Zinc.	Wani and Khan, 2012
2.	*Brassica napus*	*Bacillus megaterium*	Decreased Lead pollution in soil and increase in total yield of plant.	Reichman, 2014
3.	*Solanumlycopersicum*	*Bacillus amyloliquefaciens* and *Bacillus subtilis*	Resistance against Fusarium wilt, increase in lycopence content and improved texture of fruits	Loganathan et al., 2014
4.	*Piper nigrum* and *Cucumis sativus*	*Bacillus* spp.	P and K solubilisation, increase in fertility of soil planted with cucumber and pepper	Han and Lee, 2006
5.	*Bacillus licheniformis*	*Arachis hypogaea*	Increased saline stress tolerace, increased biomass, increased root length and total length of plant.	Dweipayan Goswami et al., 2014
6.	*Helianthus annus andTriticum aestivum*	*Bradyrhizobium japonicum*	Excess plant biomass and organic matter in soil and growth promotion in high arsenic concentration	Yavar et al. 2014

Besides bacterial species, fungal species such as *Trichoderma, Aspergillus, Alternaria* and *Penicillium* can also be used as PGPR.The PGPR promotes plant growth and development by using their own metabolism through a variety of direct or indirect mechanism such as biological nitrogen fixation, increasing the availability of nutrients in rhizosphere, enhancing the absorption of iron through siderophore production and production of phytohormones. *Azotobacter* species (*Azotobacter chroococcum* and *Azotobacter vinelandii*) and *Azospirillum* species are diazotrophs reported to fix nitrogen in on leguminous crops and other crops (Mirza et al., 2001). Inoculation of *Rhizobium* species is reported to show greater increase in growth and yield of the plant as compared to plants without *Rhizobium* sp. under field conditions (Akhtar and

Siddiqui, 2009). Strains of *Pseudomonas aeruginos, Pseudomonas putida, Burkholderia cepacia, Bacillus subtilis* and *Paenibacillus polymxa* are reported to show solubilisation of tricalcium phosphate in soluble form due to the production of organic acids.Research conducted by different scientists reported that PGPR also facilitate uptake of mineral nutrients by solubilising organic acids and siderophore production (Dazzo et al., 2000; Biswas et al., 2000). Soil bacterial isolates of*Azotobacter vinelandii,Bacillus cereus* and *Bacillus megaterium* are reported to facilitate siderophore production and thus promotes plant growth and disease suppression. Bacteria like *Pseudomonas fluorescens, Bacillus subtilis* and *Paenibacillus polymyxa* are also reported to synthesize hormones like IAA, cytokinins and gibberellins (Shilev, 2013; Kang et al., 2010).

ROLE OF PGPR IN SUSTAINABILITY

PGPR also used as bio-control agents providing resistance against plant pathogens such as bacteria, fungus and nematodes by synthesising a variety of antibiotic and antifungal compounds such as chitinolytic enzymes, siderophores, HCN, catalase, amphisin, phenazine, pyoluteorin, pyrrolnitrin, tensin, tropolone, cyclic lipopeptides.Oligomycin A, kanosamine, zwittermicin A, xanthobaccin and hence promoting induced systematic responses in the plants. *Trichoderma harzianum* is used against plant pathogens as it acts as antagonist of several soil-borne fungi such as *Rhizoctonia, Pythium,Fusarium, etc* (Hartmann et al., 2008). Applications of PGPRs in different plant species in combating different environmental problems is discussed in Table 1.Thus, direct association of PGPR (soil microbes) with plant's root causes mineral uptake from the soil, decompose organic matter, acquisition of nutrient and also help in plant growth promotion as well as suppression of phyto-pathogens (Nihorimbere et al., 2011, Mishra et al. 2016). Besides plant growth promotion and development, interest in PGPR has grown remarkably in terms of sustainable environment management as it plays major role in bioremediation, biodegradation, stress control, combating climate change and enhancement of soil fertility (Figure 1).

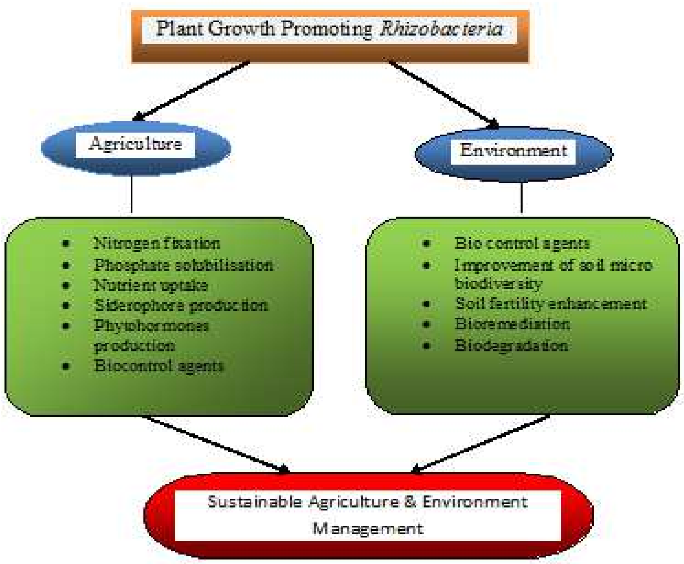

Figure 1: Multidimensional Role of PGPR on Agriculture and Environment Management

Environmental pollution due to excessive use of fossil fuels, waste generation from different anthropogenic activities, land degradation and climate change due to greenhouse gas emissions are major environmental problems so beneficial soil microbes can be incorporated for management of environmental problems. According to Zhuang et al.

(2007) and Glick (2010), soil microbes such as *Azospirillumlipoferum*, *Enterobacter cloacae, Pseudomonas putida* and *P. fluorescens* are reported to remediate soil by acting on hazardous compounds such as aromatic hydrocarbons, trichloroethane, petroleum hydrocarbons. Rhizobacteria have high metal tolerance capability therefore they are used for remediating soils contaminated with metals such as mercury, cadmium, zinc, lead, copper, etc. (Reichman, 2014). Thus, Rhizoremediation serves as an effective tool in which rhizospheric microbes are incorporated for degradation of pollutants improving the status of soil as well as preventing the plants from deleterious effects of these pollutants (Kuiper et al. 2004). Soil microbes also have the capability to absorb, accumulate, transform and degrade the pollutants present in soil. They are known to synthesise enzymes such as peroxidises, phosphatases, monooxygenases, dehalogenases and nitoreductases which degrade hazardous compounds present in soil and transform them into simpler compounds such as CO_2 and water to be released in the environment. For enhancing both plant and soil health, species like *Pantoea agglomerans, Rhizobium* spp. and *Pseudomonas* spp. are reported to improve soil texture and water holding capacity of soil (Tewari and Arora, 2014; Naseem and Bano, 2014).

CONCLUSIONS

Climate change is one of the major problems threatening the sustainability of environment and soil microbial diversity. Soil are reported as one of the largest sink of carbon but human intervention has led to the deterioration of this sink and release of carbon to atmosphere causing global warming. Rhizobacteria can be employed to combat climate change by applying them in stressed agroecosystems. PGPRs like *Achromobacter, Azotobacter, Azospirillum, Acetobacter,Bacillus, Chryseobacterium, Flavobacterium, Enterococcus,Klebsiella, Pseudomonas, Rhizobium, Serratia* and *Paenibacillus* are used for ameliorating drought and salinity stress conditions and shown decreased microbial respiratory carbon loss (Nie et al. 2015; Mishra et al. 2016).Bio fertilization, N_2-fixation and P-solubilisation, production of antibiotics, and other plant growth promoting substances are the principal contribution of the PGPRs in the agro-ecosystems. All this contribution enhances the nutrient availability for both plants and soil health eliminates the dependence of agriculture on chemicals hence increases the fertility of soil and helps in combating climate change. PGPRs can have wide applications in the restoration of waste lands when inoculated, which can be later utilised as agricultural lands and can contribute to increase land under agriculture.

Thus, it can be concluded that soil microbes (PGPRs) are endowed with number of mechanisms determining its efficacy in the field of sustainable agriculture and environment management. PGPRs can be named as sustainability indicator in terms of agriculture and environment as they are used as biofertilizers, biocontrol agents and soil fertility improvers promoting agriculture in eco-friendly manner.

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